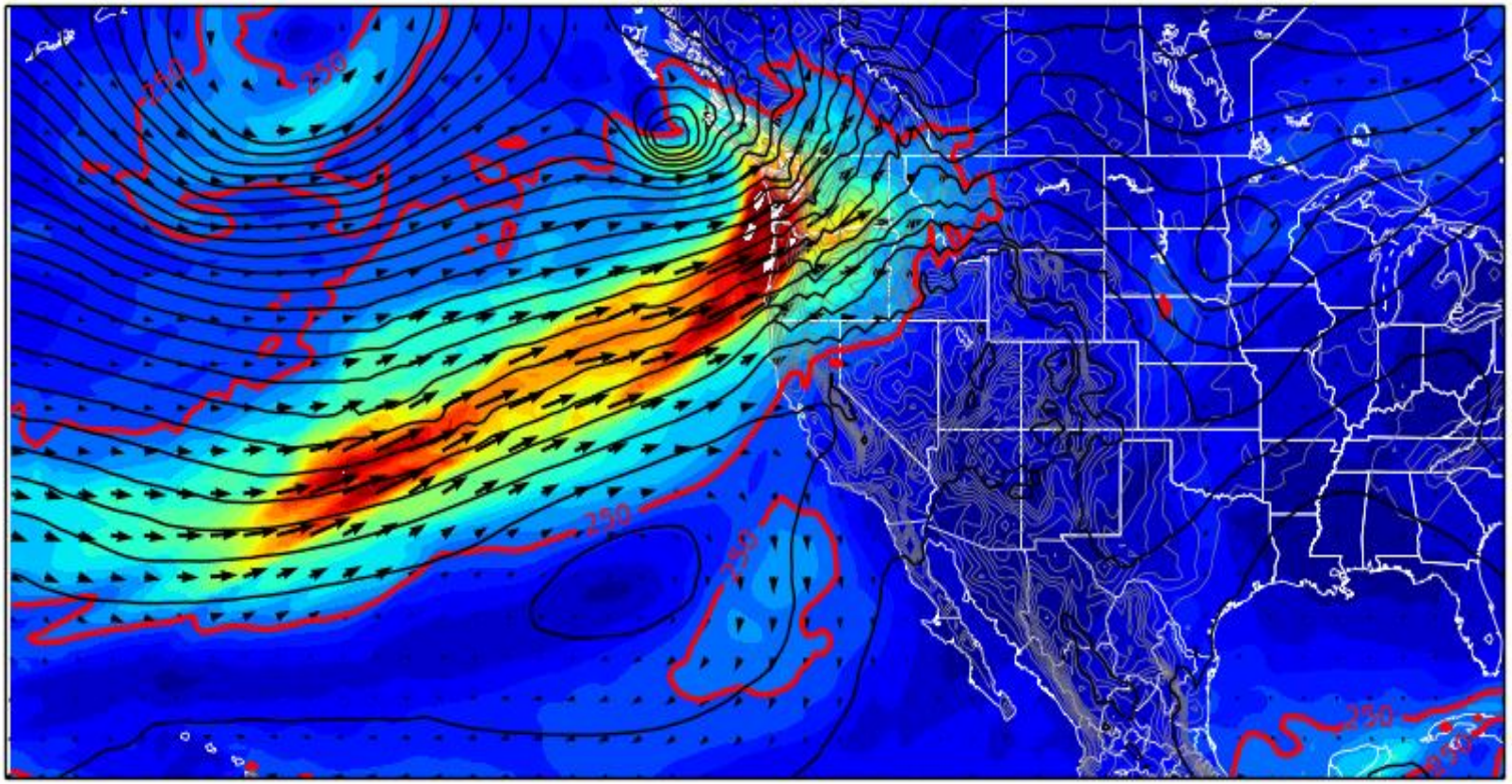
Atmospheric River Forecasting Tools



Jon Rutz – Pacific Northwest Weather Workshop – March 5th, 2016

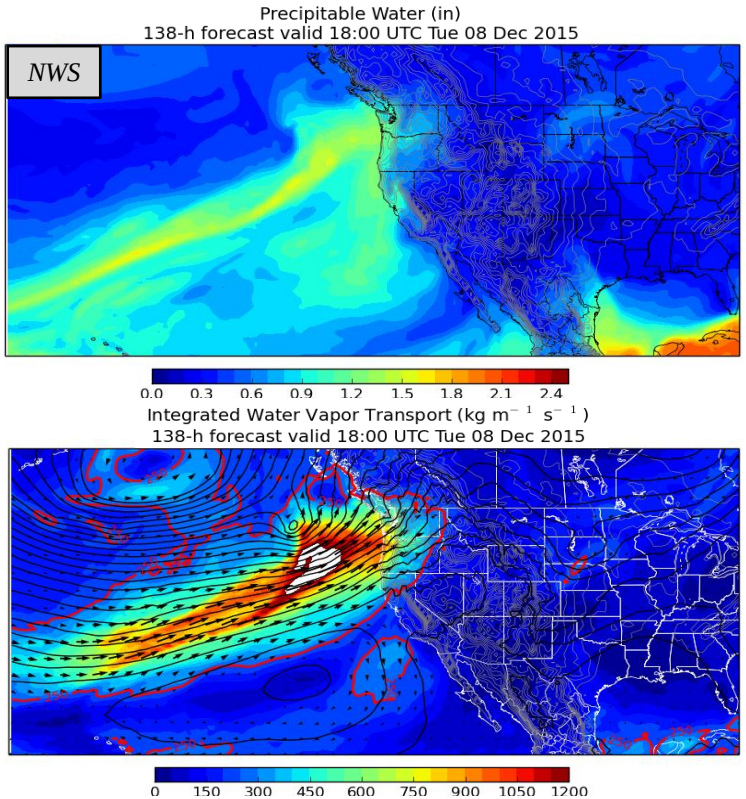
Presentation Coauthors: Jay Cordeira, Marty Ralph

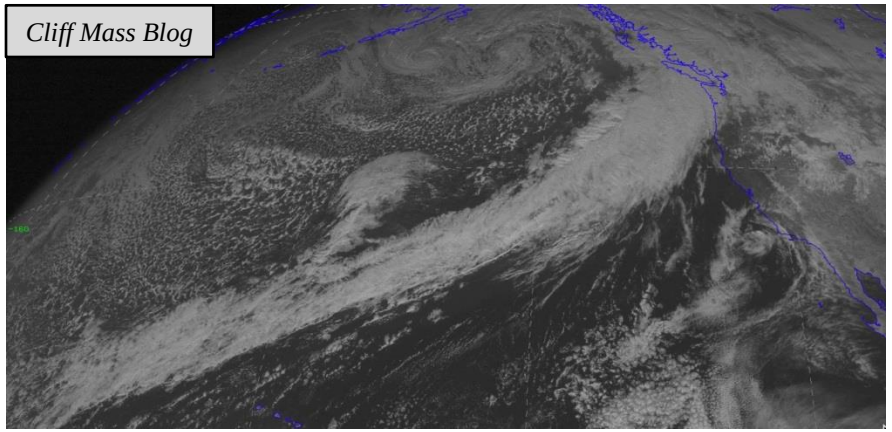
Acknowledgements: NWS WRHQ STID

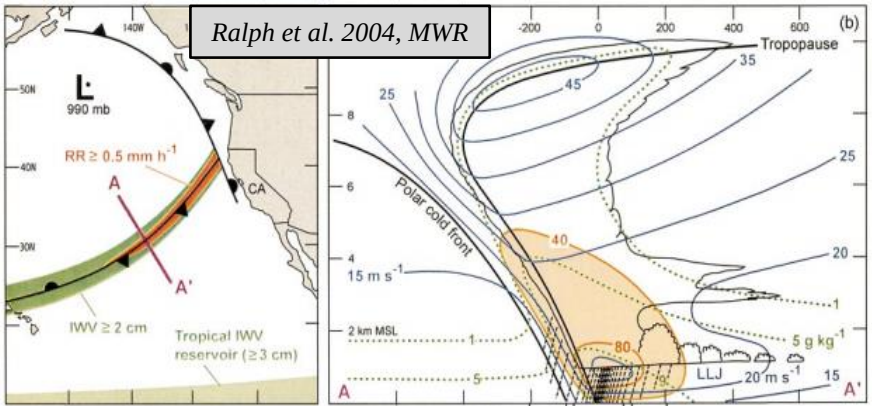
Atmospheric Rivers

- Atmospheric rivers (ARs): elongated regions of intense vertically integrated water vapor transport (IVT). Exact criteria vary, but in general, they are…
  - **Long (> 2000 km)**
  - **Narrow (< 1000 km)**
  - **Large IVT (> 250 kg m^{-1} s^{-1})**

→ **Length/Width > 2/1**



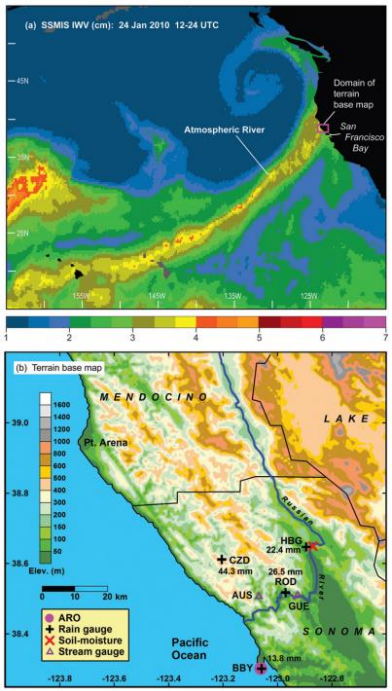


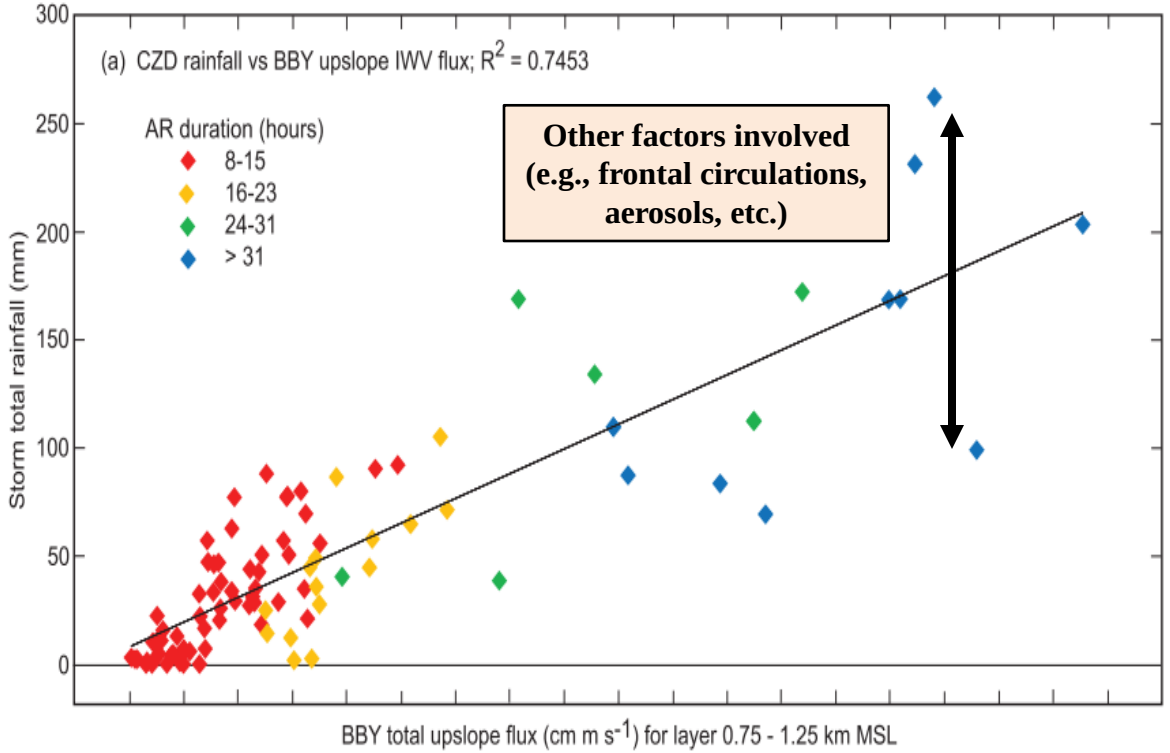


Atmospheric Rivers

Observed impacts of duration and seasonality of atmospheric-river landfalls on soil moisture and runoff in coastal northern California

Ralph, F. M., T. Coleman, P. J. Neiman, R. Zamora, and M. D. Dettinger, J. Hydrometeorology, 2013





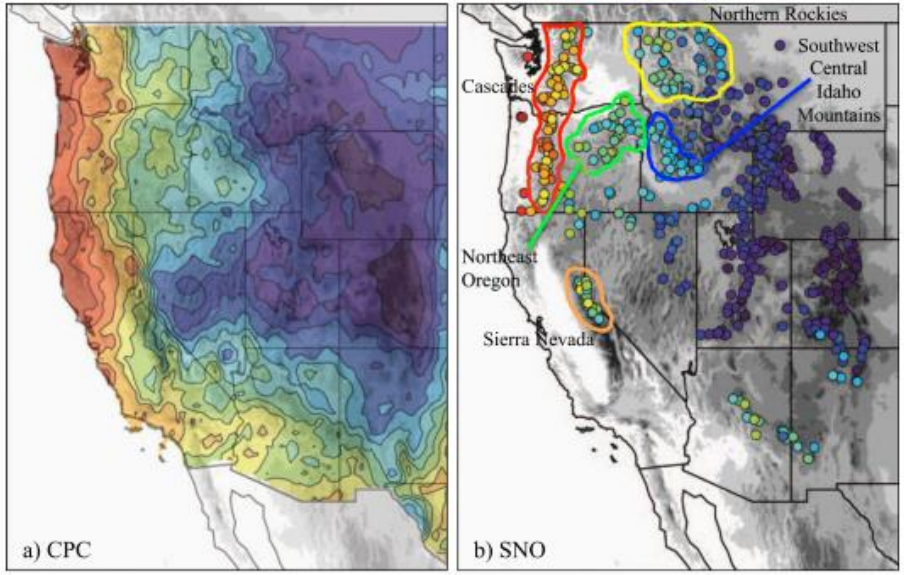
The greater the precipitation

The greater the AR strength and duration

Atmospheric Rivers

Climatological characteristics of atmospheric rivers and their inland penetration over the western United States

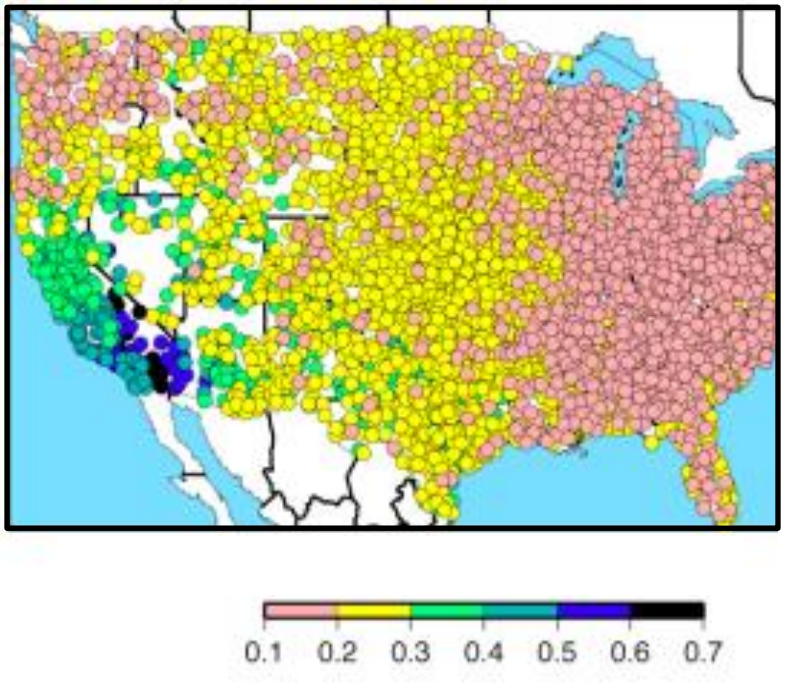
Rutz, J. J., W. J. Steenburgh, and F. M. Ralph, Mon. Wea. Rev., 2014



Fraction of cool-season (Nov – Apr) precipitation attributable to ARs based on (left) CPC analysis and (right) SNOTEL data

Atmospheric rivers, floods, and the water resources of California

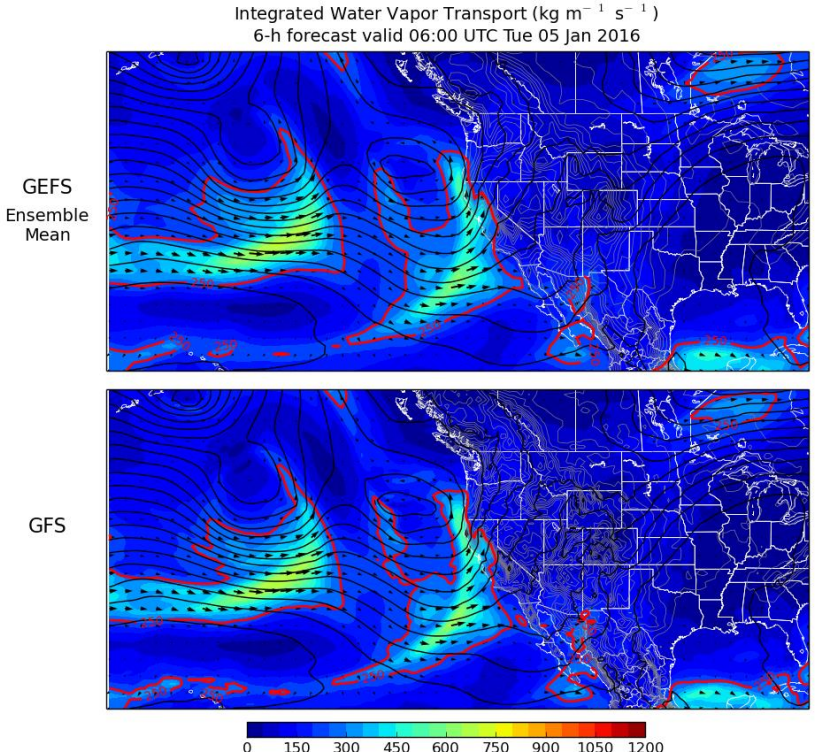
Dettinger, M. D., F. M. Ralph, T. Das, P. J. Neiman, and D. R. Cayan, Water, 2011



Coefficient of variation for annual precipitation

GEFS/GFS IVT

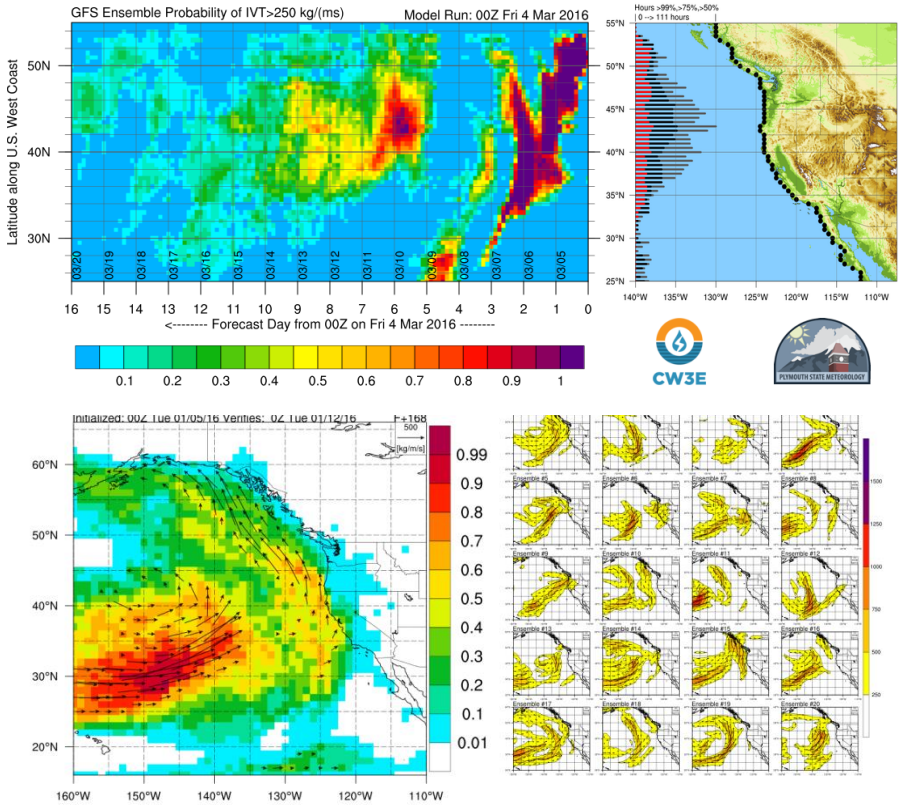
- GEFS mean and GFS forecasts of integrated water vapor transport (IVT)
- Red contour line indicates IVT > 250 kg m^{-1} s^{-1} (i.e., “AR conditions”)



- http://ssd.wrh.noaa.gov/naefs/?type=ivt

AR Portal

- GEFS mean and GFS forecasts of meteorological quantities related to atmospheric rivers (ARs), including “AR Landfall Tool”
- Developed by Jay Cordeira (Plymouth State University) in collaboration with UCSD/ SIO/CW3E (Marty Ralph)
- Not calibrated



- http://vortex.plymouth.edu/~j_cordeira/ARPortal/Current/products.html
- http://cw3e.ucsd.edu/

Situational Awareness Table

- GEFS mean forecasts of several variables, shown using a few metrics:
  - Standardized anomaly
  - Percentile
  - Return interval
  - Probability of extremes
- Calibration based on CFSR Reanalysis Climate

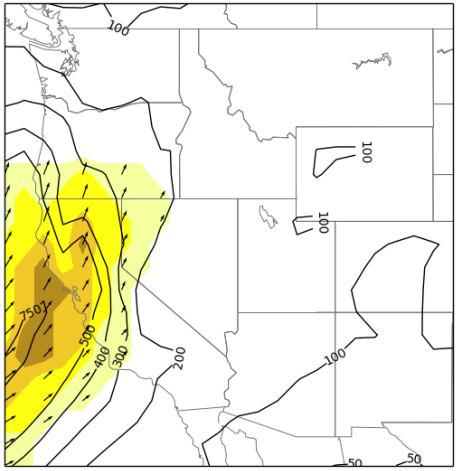
Model Run: Mar 1, 2016 00Z | Table Region: Western U.S. | Plot Region: Western U.S. | Output: NAEFS Return Interval | View Table

Fcst Hr: 120 Valid: Sat Mar

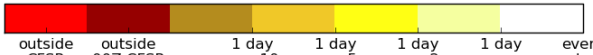
WFO Western U.S. Table Mar 1, 2016 00Z Run

			Z	T	U	V	WSP	SLP	Q	PW	IVT
0	Tue 1st	00Z	5	5	10	5	5	0-1	5	0-1	1
6		06Z	10	10	5	10	10	0-1	5	2	2
12		12Z	30	10	5	10	10	0-1	5	2	5
18		18Z	30	5	10	10	30	1	5	5	10
24	Wed 2nd	00Z	30	5	30	5	30	1	5	2	2
30		06Z	30	30	10	5	5	1	5	1	1
36		12Z	30	30	30	2	10	0-1	5	1	5
42		18Z	30	30	10	5	10	0-1	5	1	2
48	Thu 3rd	00Z	30	30	10	5	10	0-1	5	2	10
54		06Z	10	30	10	5	5	0-1	10	2	2
60		12Z	5	30	1	2	1	0-1	5	2	1
66		18Z	2	10	2	1	1	0-1	5	2	1
72	Fri 4th	00Z	1	5	1	0-1	0-1	0-1	5	2	0-1
78		06Z	1	5	0-1	2	2	0-1	2	2	1
84		12Z	1	2	1	5	5	0-1	2	1	2
90		18Z	1	5	0-1	5	2	0-1	2	1	1
96	Sat 5th	00Z	1	2	0-1	2	1	0-1	5	1	1
102		06Z	0-1	2	0-1	2	0-1	0-1	5	1	1
108		12Z	0-1	2	0-1	1	0-1	0-1	2	1	1
114		18Z	1	5	0-1	2	1	1	5	2	5
120	Sun 6th	00Z	2	5	2	5	5	2	5	2	10
126		06Z	5	2	2	5	5	5	2	1	5
132		12Z	2	1	5	5	2	2	1	1	1
138		18Z	2	1	2	1	1	2	1	0-1	1
144	Mon 7th	00Z	2	1	5	1	1	2	1	0-1	1
150		06Z	2	1	5	1	1	2	1	0-1	0-1
156		12Z	2	1	10	2	2	2	0-1	0-1	1
162		18Z	2	1	5	10	2	2	0-1	0-1	1
168	Tue 8th	00Z	5	1	5	30	2	5	0-1	0-1	1
174		06Z	5	1	2	30	5	5	0-1	0-1	1
180		12Z	5	2	2	30	5	5	0-1	0-1	1
186		18Z	5	2	2	30	5	2	0-1	0-1	1
192	Wed 9th	00Z	5	2	5	30	5	2	0-1	0-1	1
198		06Z	5	1	5	10	2	1	0-1	0-1	1
204		12Z	5	1	5	30	2	1	0-1	0-1	1
210		18Z	2	1	5	30	2	1	1	0-1	1
216	Thu 10th	00Z	2	2	5	10	2	0-1	1	0-1	1
222		06Z	5	2	5	10	1	1	0-1	0-1	1
228		12Z	2	2	2	10	1	0-1	0-1	0-1	1
234		18Z	2	2	2	5	1	0-1	0-1	0-1	1
240	Fri 11th	00Z	1	1	2	5	1	0-1	0-1	0-1	1

NAEFS Mean Integrated WV Transport ($kgm^{-1}s^{-1}$) and Return Interval
HOUR 120 - VALID 00:00 UTC Sun Mar 06 2016



Approximate frequncy of occurrence in the
24-Feb to 16-Mar CFSR climatology (1979-2009)



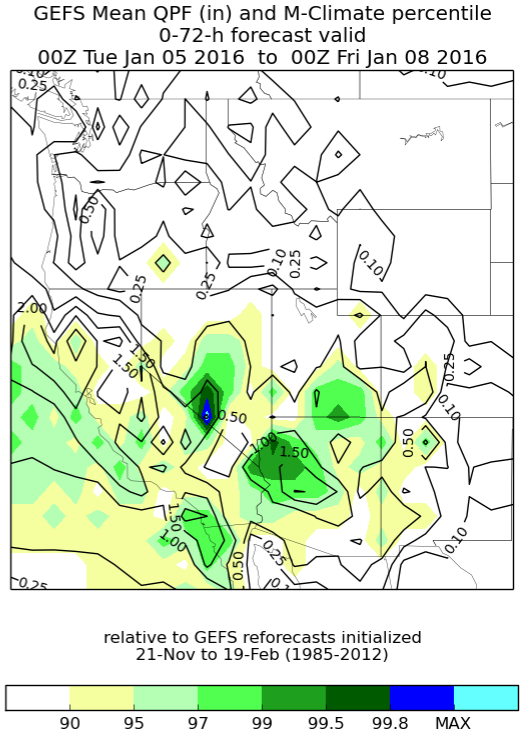
- http://ssd.wrh.noaa.gov/satable/

GEFS QPF M-Climate

- GEFS mean forecast of precipitation and how it compares to the reforecast climatology over several time periods
- Calibration based on GEFS Reforecast Climatology

WFO Western U.S. Table Jan 5, 2016 00Z Run

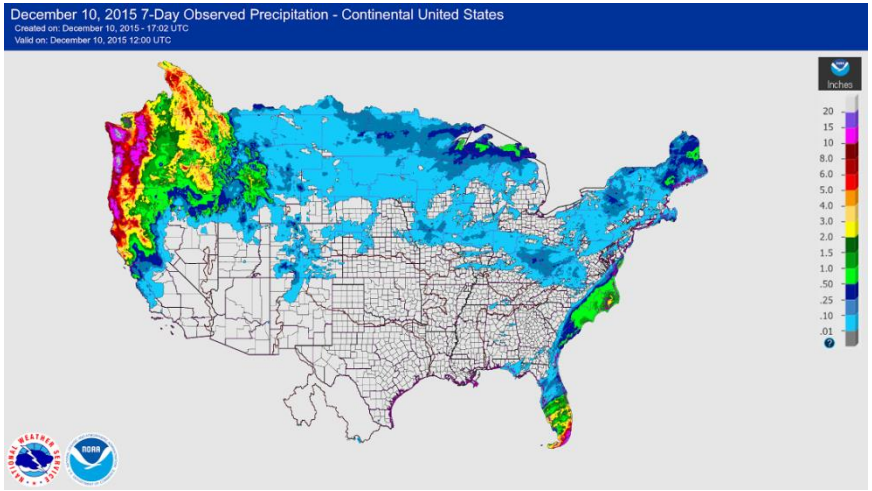
			6-h	12-h	24-h	48-h	72-h
6	Tue 5th	06Z	99.6				
12		12Z	98.9	98.7			
18		18Z	97.6	96.6			
24	Wed 6th	00Z	MAX	99.3	98.7		
30		06Z	MAX	MAX	99.5		
36		12Z	99.7	99.7	MAX		
42		18Z	MAX	MAX	99.8		
48	Thu 7th	00Z	98.8	99.8	99.5	99.6	
54		06Z	98.1	97.3	99.5	99.7	
60		12Z	98.8	99.5	99.0	MAX	
66		18Z	99.3	99.1	98.9	MAX	
72	Fri 8th	00Z	98.7	99.1	99.3	99.9	MAX
78		06Z	97.0	98.8	98.8	99.8	MAX
84		12Z	95.2	96.8	98.4	99.7	MAX
90		18Z	93.9	94.5	98.3	99.1	MAX
96	Sat 9th	00Z	93.5	96.2	97.3	99.4	99.8
102		06Z	<90	91.5	95.9	99.4	99.8
108		12Z	<90	<90	95.2	99.3	99.7
114		18Z	<90	<90	93.2	98.9	99.2
120	Sun 10th	00Z	<90	<90	93.2	98.5	99.5
126		06Z	<90	90.3	91.2	98.0	99.5
132		12Z	<90	<90	<90	96.8	99.4
138		18Z	<90	<90	90.8	96.0	99.1
144	Mon 11th	00Z	<90	<90	91.4	94.2	98.7
150		06Z	<90	<90	<90	90.5	97.7
156		12Z	<90	<90	<90	<90	96.2
162		18Z	92.1	<90	<90	<90	93.8
168	Tue 12th	00Z	95.5	95.8	92.8	<90	90.6
174		06Z	90.6	93.1	94.3	<90	<90
180		12Z	94.0	93.5	94.2	<90	91.5
186		18Z	91.3	91.5	94.5	90.9	90.5
192	Wed 13th	00Z	92.7	95.4	94.7	93.7	91.8

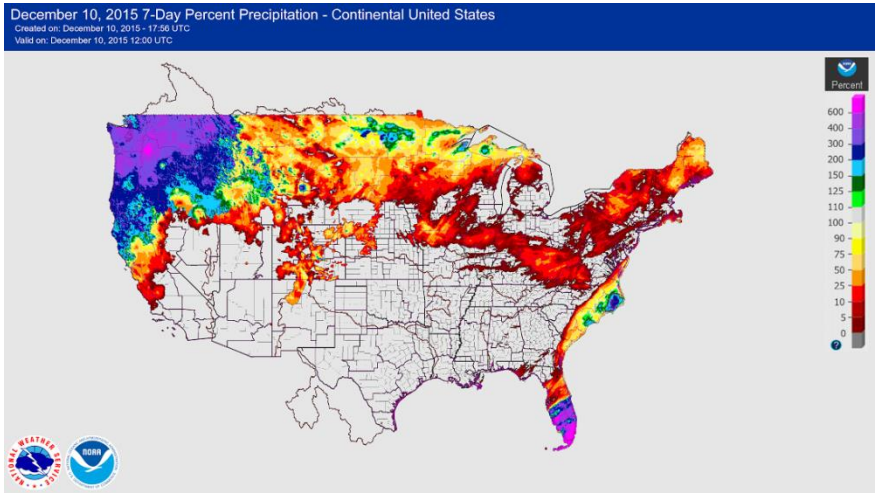


- http://ssd.wrh.noaa.gov/satable/
  - Access by selecting from “Output” menu

PacNW AR Events – December 2015

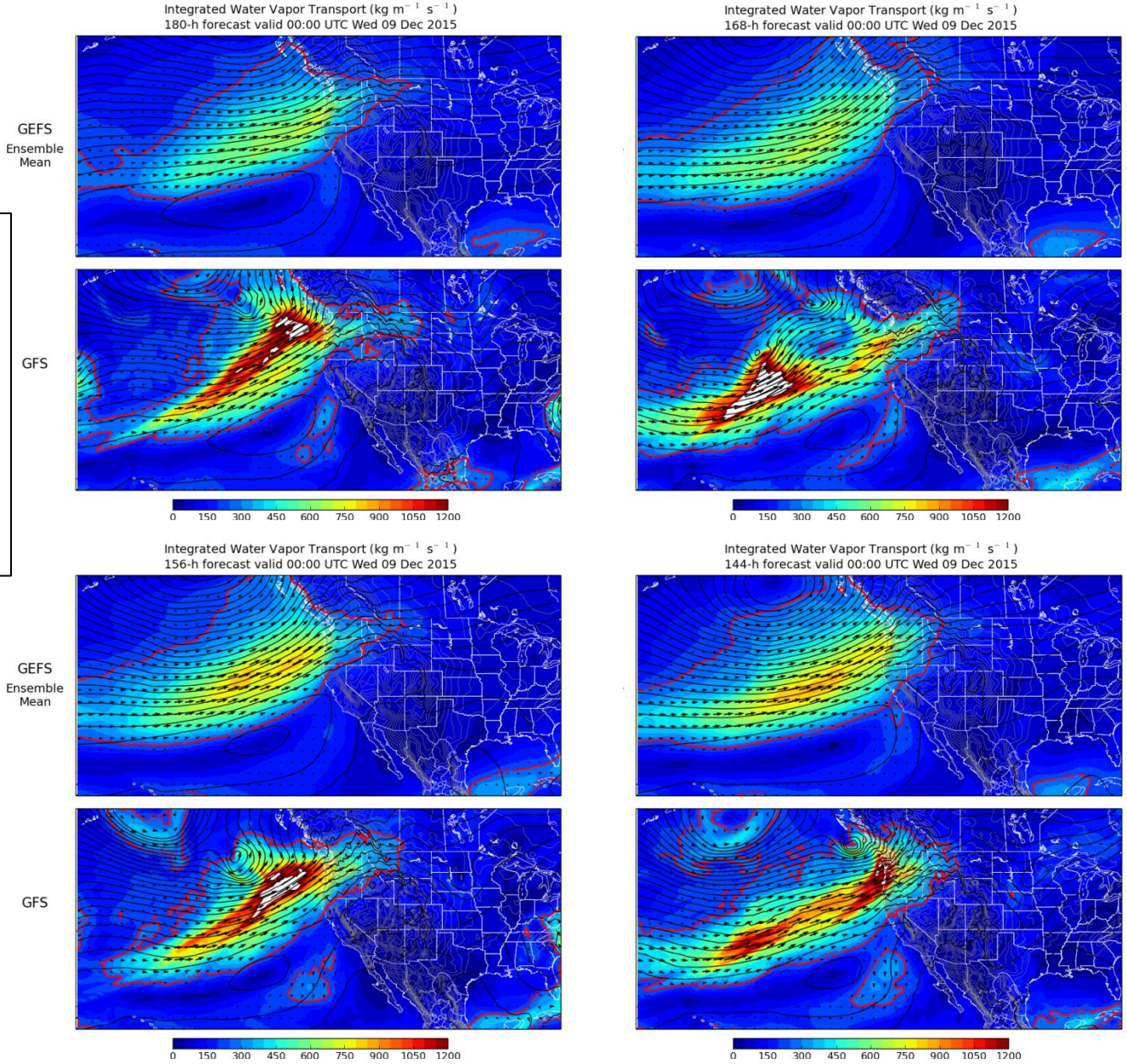
- A series of ARs impacted the PacNW during early December
  - No one AR was more extreme than a once per 5 year event for the middle of December
  - The cumulative effect, however, was quite notable and suggests there is value in looking at time-integrated IVT
  - 7-d precipitation anomalies > 400% of normal over much of the PacNW
    - Roughly translates to a month of precipitation





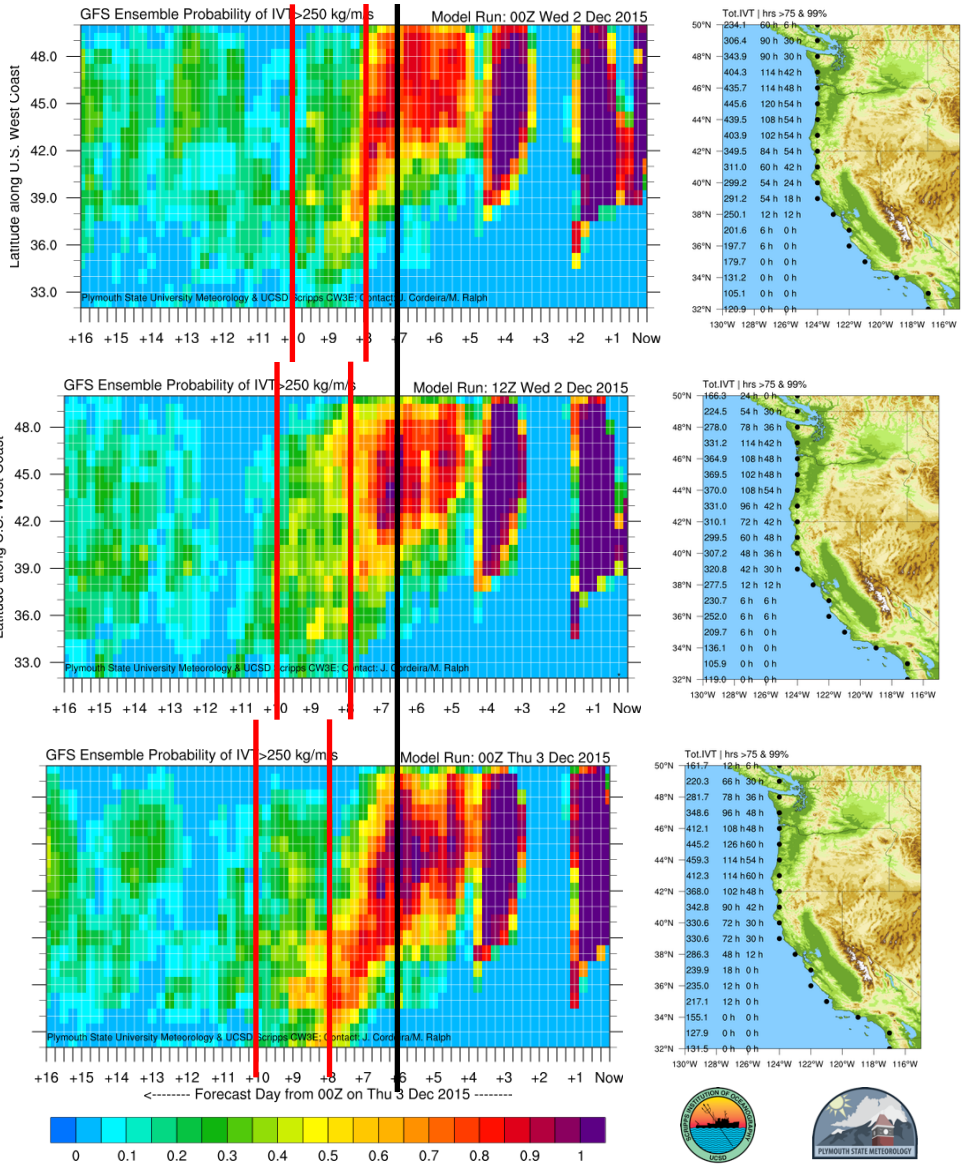
GFS/GEFS IVT dProg/dt

Note that even though deterministic GFS is bouncing around a bit, GEFS is becoming more confident (i.e., greater IVT along AR axis) with time.



AR Landfall Tool dProg/dt

Useful for visualizing trends in AR landfall location and confidence (note red lines – 8-10 d "wall" of forecast skill)

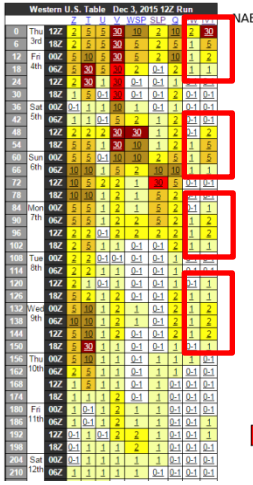


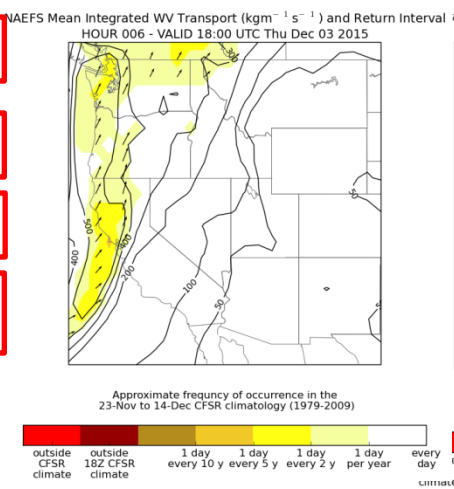
http://vortex.plymouth.edu/~j_cordeira/ARPortal/Archive/201512/2015120300/Ensemble/LandfallTool/dProgdt_IVTprob250.html

PacNW AR Events – December 2015

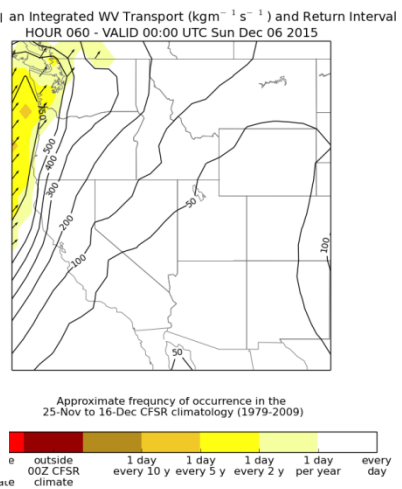
- Each AR was a meaningful event, but none were more extreme than a once per 5 year event for the middle of December
  - See return intervals for each event below
- The situational awareness table highlighted the quick succession of ARs that would impact the region

Event #1

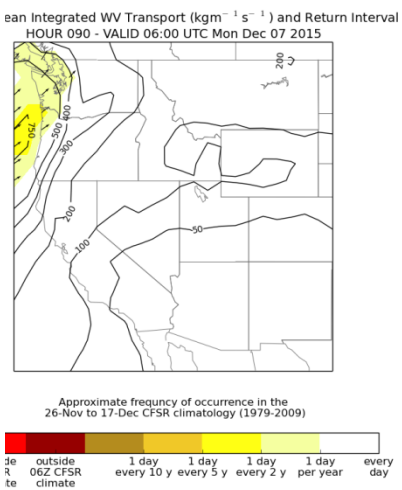




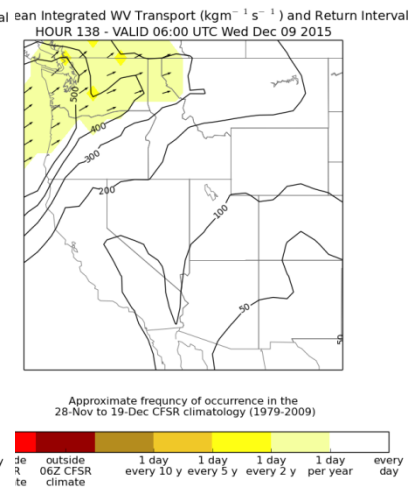
Event #2



Event #3



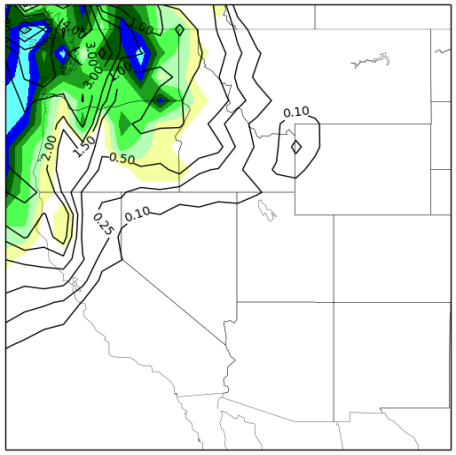
Event #4



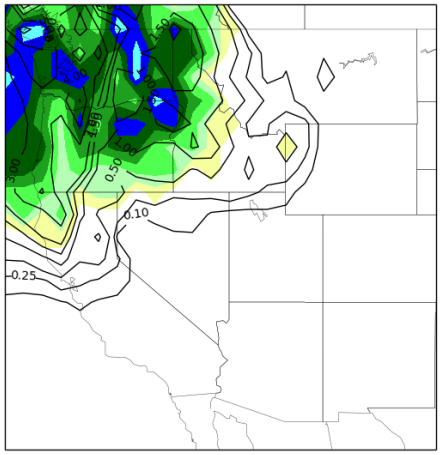
GEFS M-Climate Percentiles

Western U.S. Table Dec 3, 2015 00Z Run							
			6-h	12-h	24-h	48-h	72-h
6	Thu 3rd	06Z	99.6				
12		12Z	99.8	99.9			
18		18Z	99.9	99.9			
24	Fri 4th	00Z	98.9	99.8	MAX		
30		06Z	96.0	98.2	99.9		
36		12Z	95.3	94.3	99.5		
42		18Z	96.0	93.5	95.4		
48	Sat 5th	00Z	90.3	93.8	92.9	99.9	
54		06Z	<90	<90	<90	99.6	
60		12Z	94.9	<90	<90	98.7	
66		18Z	99.9	99.8	98.3	98.7	
72	Sun 6th	00Z	MAX	99.9	99.8	99.0	MAX
78		06Z	99.9	MAX	MAX	99.6	MAX
84		12Z	99.9	MAX	MAX	99.8	MAX
90		18Z	98.0	99.3	MAX	99.9	99.9
96	Mon 7th	00Z	98.2	98.5	99.9	MAX	99.8
102		06Z	97.6	98.5	99.5	MAX	99.9
108		12Z	MAX	99.7	99.8	MAX	MAX
114		18Z	99.8	MAX	MAX	MAX	MAX
120	Tue 8th	00Z	99.8	99.8	MAX	MAX	MAX
126		06Z	97.7	99.3	MAX	MAX	MAX
132		12Z	97.6	98.6	99.9	MAX	MAX
138		18Z	99.6	99.2	99.8	MAX	MAX
144	Wed 9th	00Z	MAX	MAX	MAX	MAX	MAX
150		06Z	MAX	MAX	MAX	MAX	MAX
156		12Z	99.9	MAX	MAX	MAX	MAX
162		18Z	99.9	MAX	MAX	MAX	MAX
168	Thu 10th	00Z	MAX	MAX	MAX	MAX	MAX
174		06Z	99.6	99.9	MAX	MAX	MAX
180		12Z	99.6	99.7	99.9	MAX	MAX
186		18Z	99.8	99.9	MAX	MAX	MAX
192	Fri 11th	00Z	99.7	99.8	99.9	MAX	MAX

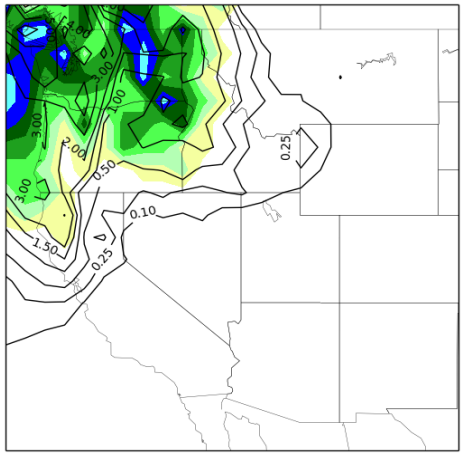
GEFS Mean QPF (in) and M-Climate percentile
72-144-h forecast valid
00Z Sun Dec 06 2015 to 00Z Wed Dec 09 2015



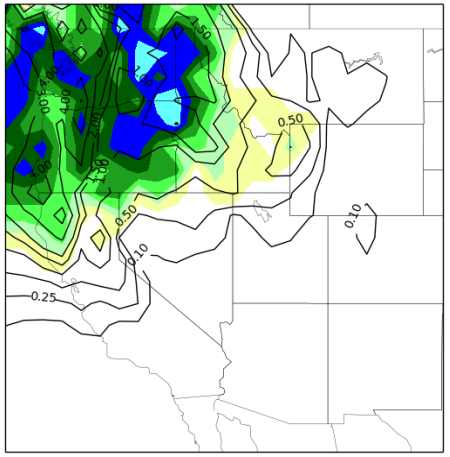
GEFS Mean QPF (in) and M-Climate percentile
96-168-h forecast valid
00Z Mon Dec 07 2015 to 00Z Thu Dec 10 2015



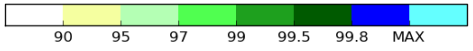
GEFS Mean QPF (in) and M-Climate percentile
84-156-h forecast valid
12Z Sun Dec 06 2015 to 12Z Wed Dec 09 2015



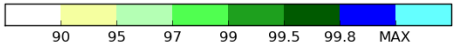
GEFS Mean QPF (in) and M-Climate percentile
108-180-h forecast valid
12Z Mon Dec 07 2015 to 12Z Thu Dec 10 2015



relative to GEFS reforecasts initialized
19-Oct to 17-Jan (1985-2012)



relative to GEFS reforecasts initialized
19-Oct to 17-Jan (1985-2012)



Summary

- Recently developed tools allow us to better anticipate atmospheric rivers and their associated impacts
  - December 2015 Pacific Northwest case highlights their usefulness

- These tools are probabilistic in nature and allow us to quantitatively discuss intensity, timing, and location, as well as put events in climatological context

- The current set of tools is very “GEFS”-centric and if the GEFS is not performing well, the tools will not perform well

2016 International Atmospheric Rivers Conference

Scripps Institution of Oceanography - La Jolla, California
8th – 11th August 2016

http://cw3e.ucsd.edu/ARconf2016

Many regions face either drought or flood, or are challenged by regional water management issues. Recent advances in atmospheric sciences and hydrology have identified the key role of atmospheric rivers (AR) in determining the distribution of strong precipitation events in midlatitudes. Combined with related phenomena, warm conveyor belts (WCB) and tropical moisture exports (TME) (Fig. 1), the frequency, position and strength of ARs determines the occurrence of water extremes. This conference brings together experts across atmospheric, hydrologic, oceanic and polar science, water management and civil engineering to advance the science and explore needs for new information.

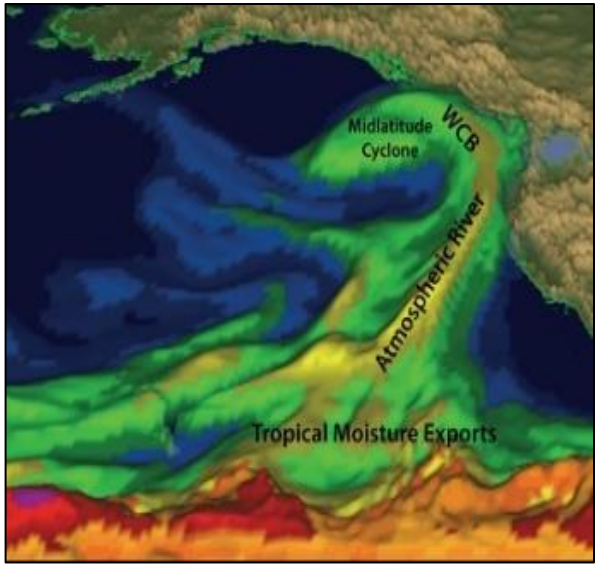


Fig. 1. Depiction of an atmospheric river, interacting with West Coast mountains. Credit: Adapted from NOAA/ESRL Physical Sciences Division. Source: EOS Meeting Report.

Conference Goals

(1) Evaluate the current state and applications of the science of the mid-latitude atmospheric water cycle, with particular emphasis on ARs and associated processes (e.g., WCB and TME)

(2) Discuss differing regional perspectives

(3) Assess current forecasting capabilities

(4) Plan for future scientific and practical challenges

International organizing committee

Allen White (*NOAA ESRL/PSD; Co-Chair*)
Irina Gorodetskaya (*K.U. Leuven, Netherlands; Co-Chair*)
Andrew Martin (*CW3E, Scripps; Co-Chair*)
Maximiliano Viale (*Universidad de Chile; Co-Chair*)
Mike Dettinger (*USGS, CW3E*)
David Lavers (*Scripps Inst. Oceanography/CW3E*)
Nina Oakley (*Desert Research Institute*)
F. Martin Ralph (*Scripps Inst. Oceanography/CW3E*)
Jonathan Rutz (*U. S. National Weather Service*)
Ryan Spackman (*Science and Technology Corporation*)
Heini Wernli (*ETH Zurich*)

The conference will be held at the beautiful oceanfront venue of the Robert Paine Scripps Forum for Science, Society and the Environment located at the Scripps Inst. of Oceanography, Univ. of CA – San Diego.

Contributions for the 2016 Conference are now invited
For further information or to submit an abstract, please contact:
Mike Dettinger (mddettin@usgs.gov) or
Mary Tyree (mtyree@ucsd.edu)
http://cw3e.ucsd.edu/ARconf2016

Center for Western Weather and Water Extremes

Links

- WR Forecast Confidence Toolkit: https://sites.google.com/a/noaa.gov/nws-wr-stid/projects/forecast-confidence
- GEFS/GEFS IVT:
  - http://ssd.wrh.noaa.gov/naefs/?type=ivt
- Situational Awareness Table:
  - http://ssd.wrh.noaa.gov/satable/
  - GEFS QPF M-Climate accessed by selecting from “Output” menu
- AR Portal:
  - http://vortex.plymouth.edu/~j_cordeira/ARPortal/Current/products.html
  - Archive: http://vortex.plymouth.edu/~j_cordeira/ARPortal/Archive/
- ESRL GEFS Reforecast (Calibrated) Precipitation and EFI:
  - http://www.esrl.noaa.gov/psd/forecasts/reforecast2/analogs/index.html
  - http://www.esrl.noaa.gov/psd/forecasts/reforecast2/analogs/pctile_thumbs.html
- ECMWF Normalized Spread:
  - http://www.ecmwf.int/en/forecasts/charts/medium/ensemble-mean-and-spread-four-standard-parameters

WR Forecast Confidence Toolkit

- Highlights a set of forecasting tools that are quantitative, user-friendly, and probabilistic (ensemble based) in nature
  - Goal is to provide expert DSS based on state-of-the-art science
- Qualitative vs. quantitative
  - Qualitative: “That’s the biggest storm I’ve seen in the GEFS this year.”
  - Quantitative: “The GEFS mean forecast 500mb heights have a return interval of once every 2-5 years during this time of year.”

- **This presentation will focus on the tools that we use to assess atmospheric river (AR) timing, location, and intensity**

- WR Forecast Confidence Toolkit: https://sites.google.com/a/noaa.gov/nws-wr-stid/projects/forecast-confidence